Prioritized Technology: Heat Shield Technologies for Planetary Entry and Sample Return – Thermal Protection Systems

Technical Goal

- Thermal Protection Systems (TPS) and integrated entry vehicle system technologies are required to accomplish missions at the most challenging destinations in the Solar System. TPS and entry vehicle technologies are also required for high-speed Earth return of samples from various Solar System bodies such as comets, asteroids, moons, and other planets. To support the majority of the foreseeable science missions, the required technologies must have the following capabilities while simultaneously prioritizing mass minimization:
  1. Peak heating rates of 5,000 W/cm^2 with stagnation pressures of >5 atm.
  2. Low likelihood of failure ($<10^{6}$ probability) for biological sample return.
- TPS materials must be affordably sustainable given the SMD mission cadence and require the completion of low-level assessments & batch production/testing every two years.
- Flight environments cannot be affordably replicated on Earth necessitating the need to perform advanced analyses to quantify and certify requirements, material/system performance, and reliability.
  - Aerodynamics, aerothermodynamics, and material response experimental data is required to validate analytical models for improving future designs and informing mission risk postures.
  - Sensors and TPS instrumentation is required to obtain performance data for mission reconstruction and improved atmospheric science return.

Mission Applications

- The successful technology maturation of HEEET will enable the use of a single TPS material for the most likely Venus, Uranus, Saturn and Earth-return science missions.
  - Science missions exceeding these entry conditions would be evaluated on an individual basis.
- Reduced entry system mass will result in lower launch/qualification costs for science missions of interest.
- HEET will enable the high-speed Earth return of potentially biologically-active samples with a probability of failure/contamination less than 10^{-6}.

Technical Status

- **Heritage Science Mission TPS:**
  - Heritage PICA has been used for Earth Return (Stardust, OSIRIS-REx, MSL, and planned for Mars 2020) but is no longer sustainable due to rayon manufacturing being discontinued.
    - The Stardust design included a 0.83 meter monolithic PICA heatshield with a peak heat load of 1,200 W/cm^2.
    - The Pioneer design included a 0.76 – 1.42 meter carbon phenolic heat shield with a peak heat load of 3,900 – 5,500 W/cm^2.
  - Carbon Phenolic (CP) has been successfully used for Galileo missions but had mass fractions in excess of 50% and resulted in entry loads exceeding 300 g's. Further, CP is no longer supported by the manufacturing supply chain.
- **Recent SMD Technology Development Efforts**:
  - Woven TPS (HEEET) is being matured to TRL 6 by SMD and STMD and has been successfully tested to 5,000+ W/cm^2.
    - These test conditions are anticipated to envelope the most probable Venus, Uranus, Saturn & Earth-return science missions.
    - Missions to Saturn and Ice Giants will likely exceed these entry conditions and will require additional evaluation.
  - SMD is funding the maturation of a more sustainable PICA formulation which has been tested to 1,500 W/cm^2.
    - PICA is a less capable, but more affordable & lower mass, TPS alternative to HEEET.

Development Cost and Schedule

**HEEET cost profile is mission-dependent.*

1/26/2018